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ENVIRONMENTAL POLICY, PUBLIC GOODS AND THE MARGINAL COST OF PUBLIC FUNDS*

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If private goods are perfect substitutes for public goods and environmental quality, greener preferences reduce employment, raise abatement and improve environmental quality. If the elasticity of substitution between private goods and leisure exceeds one, the tax rate increases, thereby reducing private consumption. However, if labour supply bends backwards, private utility rises while the tax rate and public consumption fall. With imperfect substitution between private and public consumption, greener policies boost labour supply if the substitution elasticity between private and public consumption and the elasticity of the effectiveness of public abatement are small and the labour supply curve bends backwards.

Many politicians argue that revenues from pollution taxes should be used to reduce other distortions in the economy. This may yield a 'double dividend' in the sense that both environmental quality and employment will rise (cf. Pearce, 1991). Environmental policy also raises other important issues. Under what conditions is a cleaner environment compatible with a higher rather than a lower level of public consumption? Does a cleaner environment require a fall in private utility? How does environmental policy affect the tax level and composition of public spending? This paper addresses some of these policy questions.

Taxes serve the dual purpose of, on the one hand, generating revenues to finance a sizeable public sector and, on the other hand, internalising environmental externalities. Sandmo (1975) considers optimal taxation when there are externalities in private consumption but assumes an exogenous public revenue target. Bovenberg and van der Ploeg (1992) extend Sandmo's results to the optimal provision of public goods while allowing for a rich mix of policy instruments, viz. public consumption of both dirty and clean goods, public abatement, a tax on private consumption of dirty goods and the labour tax. Their main result is that the 'double dividend' hypothesis fails, i.e. greener preferences generally reduce employment. This paper examines production externalities and imperfect substitution between private and public components of welfare and studies the impact of more environmental concern.

I. TAXATION, PUBLIC GOODS, AND ENVIRONMENTAL EXTERNALITIES

Households receive income from employment (bL where b denotes the production wage and L stands for hours worked). Households spend after-tax income on consumption (C), i.e. $C = (1-t)\,bL$ where t denotes the tax rate. Households derive private utility (M) from consumption (C) and leisure ($V = 1-L$, where the number of hours available to households is normalised at unity). Households also obtain utility from public consumption (G) and

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environmental quality (E). Environmental quality declines with production (Y), but can be enhanced through public abatement (A). For example, the government may step in to clean up polluted soil arising from dumping of hazardous materials in the past. Utility is quasi-linear:

$$U \equiv M(C, V) + \gamma_G G + \gamma_E[e(A) - aY], \quad \gamma_G > 0, \quad \gamma_E > 0, \quad e' > 0, \quad e'' < 0, \tag{1}$$

where a is the emission-output ratio and $e(.)$ represents the effectiveness of public abatement. $M(.)$ is concave and weakly homothetic. Households take wages, prices, the tax rate, public consumption and environmental quality as given. Households equate the marginal rate of substitution between consumption and leisure to the after-tax wage (w), i.e. $M_V/M_C = (1-t)\,b \equiv w$. From the household budget, we obtain $C = c(w)$, $V = 1 - l(w)$, $M = m(w)$ where $m(.)$ denotes indirect private utility. Roy's identity gives labour supply, i.e. $L = m_w/\lambda$ where $\lambda = M_C$ denotes marginal private utility of private income. The (uncompensated) elasticity of labour supply is $\epsilon_L \equiv wl_w/L = (\sigma_M - 1)V$ where σ_M stands for the substitution elasticity between C and V. Labour supply slopes upwards (bends backwards) if the substitution effect dominates (is outweighed by) the income effect, i.e. if σ_M exceeds (is less than) unity.

Labour market equilibrium implies that unemployment is voluntary, i.e. $L + V = 1$. Equilibrium on the commodity market requires that total demand for goods, consisting of private consumption (NC where N denotes the number of households), public consumption (G) and public abatement (A), is constrained by total output (Y), i.e. $Y \equiv bNL = NC + G + A$. Output is proportional to employment and producer prices are fixed (without loss of generality at unity). Labour tax revenues finance public spending, i.e. $tbNL = G + A$.

The government chooses public consumption (G), public abatement (A) and the tax rate (t), but not lump-sum taxes or subsidies, to maximise social welfare (W), i.e.

$$W \equiv NU = Nm[(1-t)\,b] + N\gamma_G G + N\gamma_E\{e(A) - aNbl[(1-t)\,b]\}, \tag{2}$$

subject to $tbNl[(1-t)b] = G + A$. This yields for public consumption and abatement $N\gamma_G = N\gamma_E e'(A) = \mu$ where μ is the marginal disutility of raising a unit of government revenues. Each pound of public spending must thus yield the same marginal utility, irrespective of whether it is used for public consumption or abatement. Alternatively, we have:

$$N\gamma_G/M_C = \eta \equiv \mu/\lambda \quad \text{and} \quad e'(A) = a/t_N, \quad t_N \equiv (Na\gamma_E/M_C\,\eta) = a\gamma_E/\gamma_G. \tag{3}$$

Hence, the sum of the marginal rates of substitution between public and private consumption should equal the marginal cost of public funds (η or the MCPF), which can diverge from the marginal rate of transformation between public and private goods (i.e. unity). This modified Samuelson rule implies that scarcer public funds (and thus a higher η) causes substitution away from public

towards private consumption. Since $e'' < 0$, the optimal level of public abatement increases with the implicit price of the environment (i.e. t_N/a which is the non-distortionary level of the tax rate scaled by the emission-output ratio). The marginal rate of substitution between environmental quality and public goods (γ_E/γ_G) must equal the implicit price of the environment. If the MCPF is unity (e.g. if lump-sum taxes and subsidies are available), the non-distortionary level of the tax rate corresponds to the textbook Pigovian tax rate, i.e. the sum of the marginal environmental damages ($Na\gamma_E$ scaled by M_C to convert from utility units into pounds). If a high MCPF indicates that tax revenue is scarce, pollution does not have to yield as much tax revenue to offset the environmental damage. Hence, the non-distortionary pollution tax rate (t_N) falls with the MCPF. Alternatively, a high MCPF indicates that the government can afford less to internalise environmental externalities.

For the tax rate, we obtain (upon use of Roy's identity and substitution of (3) for t_N):

$$\eta \equiv \mu/\lambda = (1-t)/[1-t-(t-t_N)\,\epsilon_L] = (1-t)/[1-t-(\sigma_M-1)\,V(t-t_N)]. \tag{4}$$

If labour supply slopes upwards ($\epsilon_L > 0$, $\sigma_M > 1$) and the tax rate exceeds its non-distortionary level ($t > t_N$), the MCPF exceeds the marginal rate of transformation between public and private goods (i.e. unity). An increase in public revenues then exacerbates the deadweight loss of distortionary taxation and raises the MCPF above unity. However, if $t > t_N$ and labour supply bends backwards ($\epsilon_L < 0$, $\sigma_M < 1$), the MCPF is less than unity. If labour supply is inelastic ($\epsilon_L = 0$, $\sigma_M = 1$), the MCPF equals unity.

II. COMPARATIVE STATICS OF THE SECOND-BEST OUTCOME

II.a. Private behaviour, market equilibrium and government policy

Loglinearising $M_V/M_C = w$ (i.e. $\tilde{C}-\tilde{V} = \sigma_M\,\tilde{w}$), $V+L = N$ (i.e. $V\tilde{V}+L\tilde{L} = 0$) and the household budget (i.e. $\tilde{C} = \tilde{w}+\tilde{L}$), where logarithmic deviations are denoted by a tilde (e.g. $\tilde{L} \equiv dL/L$) except $\tilde{t} \equiv dt/(1-t) = -\tilde{w}$, yields:

$$\tilde{L} = -\epsilon_L\,\tilde{t}, \quad \tilde{V} = \epsilon_L(L/V)\,\tilde{t}, \quad \tilde{C} = -(1+\epsilon_L)\,\tilde{t}, \quad \tilde{M} = -L\,\tilde{t}$$
$$\text{with} \quad \epsilon_L = (\sigma_M-1)\,V. \tag{5}$$

We use (5) to loglinearise the government budget constraint:

$$\omega_G\,G+\omega_A\,A = L-\omega_C\,C = [\omega_C-\epsilon_L(1-\omega_C)]\,\tilde{t} = (1-t-\epsilon_L\,t)\,\tilde{t}, \tag{6}$$

where $\omega_C \equiv NC/Y = 1-t$, $\omega_G \equiv G/Y$ and $\omega_A \equiv A/Y$. The left-hand side of (6) stands for overall public spending; the first term in the bracket of the last right-hand side ($1-t = \omega_C$) corresponds to the 'tax rate' effect while the second term in this bracket ($-\epsilon_L\,t$) stands for the 'tax base' effect. If labour supply slopes upwards (bends backwards), i.e. σ_M is greater (less) than unity, a higher tax rate narrows (broadens) the tax base and tax revenues thus rise less (more) than proportionally with the tax rate. We rule out a downward-sloping Laffer-curve, so $\epsilon_L < (1-t)/t$.

Substituting (6) into (5) to eliminate $\tilde{t}$, we see that private utility suffers from higher public spending due to the higher tax rate required to finance this spending:

$$\tilde{M} = -L\Delta^{-1}(\omega_G \tilde{G} + \omega_A \tilde{A}), \quad \text{where} \quad \Delta \equiv (1-t) - \epsilon_L t > 0. \tag{7}$$

The changes in public abatement and the non-distortionary tax rate follow from (3):

$$\tilde{A} = (\tilde{t}_N - \tilde{a})/\sigma_A = (\tilde{\gamma}_E - \tilde{\gamma}_G)/\sigma_A \quad \text{and} \quad \tilde{t}_N = \tilde{a} + \tilde{\gamma}_E - \tilde{\gamma}_G, \tag{8}$$

where $\sigma_A \equiv -Ae''/e' > 0$ is the elasticity of the effectiveness of public abatement. More environmental concern ($\tilde{\gamma}_E > 0$) or less priority for public consumption ($\tilde{\gamma}_G < 0$) raises the non-distortionary level of the tax rate. This pushes up the shadow price of the environment (t_N/a) which in turn induces the government to undertake more abatement. Using $\tilde{M}_C = (\tilde{V} - \tilde{C})V/\sigma_M$ and (5), we obtain for the modified Samuelson rule (3):

$$\tilde{\gamma}_G - V\tilde{t} = \tilde{\gamma}_G + (V/L)\,\tilde{M} = \tilde{\eta}. \tag{9}$$

The change in the MCPF follows from (4):

$$\tilde{\eta} = \epsilon_L \eta (1-t)^{-1}[(\kappa + t - t_N)\,\tilde{t} - t_N \tilde{t}_N] = \\ -\epsilon_L \eta (1-t)^{-1}[t_N \tilde{t}_N + (\kappa + t - t_N)\,L^{-1}\tilde{M}], \tag{10}$$

where $\kappa \equiv 1 - t + (t - t_N)(\sigma_M - 1)L$. We assume that $\kappa > 0$.[1]) If labour supply slopes upwards ($\sigma_M > 1$), a higher tax rate raises the MCPF and makes public consumption and abatement more expensive (as we assume that $\kappa + t - t_N > 0$). Increases in environmental concern ($\tilde{\gamma}_E > 0$) or the emission–output ratio ($\tilde{a} > 0$) boost the non-distortionary tax rate (see (8)). The higher non-distortionary tax rate reduces the MCPF if labour supply slopes upwards. This induces substitution away from private towards public spending, including abatement (see (9)). If, in contrast, labour supply bends backwards ($\sigma_M < 1$), greener preferences or a higher emission–output ratio raise the MCPF. Substituting (10) and (8) into (9) and solving for $\tilde{\eta}$ and $\tilde{t}$ yields:

$$\tilde{\eta} = \left(\frac{\sigma_M - 1}{\kappa\sigma_M}\right)\{-t_N V(\tilde{a} + \tilde{\gamma}_E) + [1 - Lt + L\sigma_M(t - t_N)]\,\tilde{\gamma}_G\}, \tag{11}$$

$$\tilde{t} = \frac{t_N}{\kappa}\left(\frac{\sigma_M - 1}{\sigma_M}\right)(\tilde{a} + \tilde{\gamma}_E) + \left(\frac{\Delta}{\kappa V \sigma_M}\right)\tilde{\gamma}_G. \tag{12}$$

II.b. Private utility, public consumption and environmental quality

When we use (11) in (9), we obtain for private utility:

$$\tilde{M} = -\left[\frac{(\sigma_M - 1)\,L}{\kappa\sigma_M}\right] t_N(\tilde{a} + \tilde{\gamma}_E) - \left(\frac{\Delta L}{\kappa\sigma_M V}\right)\tilde{\gamma}_G. \tag{13}$$

Clearly, $\tilde{L} = (\epsilon_L/L)\,\tilde{M}$ and $\tilde{C} = (1 + \epsilon_L)\,L^{-1}\tilde{M}$ follow directly from (13). As

[1] If $t > t_N$, then $t < \frac{1}{2}$ is sufficient for $\kappa > 0$. If $t < t_N$, then $t_N(\sigma_M - 1) < 1$ is sufficient for $\kappa > 0$.

long as labour supply is not completely inelastic, $\tilde{L}$ is a negative function of $\tilde{a}+\tilde{\gamma}_E$ irrespective of whether σ_M exceeds or is less than one. Public consumption ($\tilde{G}$) follows by using (8) and (13) in (7):

$$\omega_G \tilde{G} = \left[\frac{\Delta t_N(\sigma_M - 1)}{\kappa\sigma_M}\right](\tilde{a}+\tilde{\gamma}_E) - \left(\frac{\omega_A}{\sigma_A}\right)\tilde{\gamma}_E + \left(\frac{\Delta^2}{\kappa\sigma_M V} + \frac{\omega_A}{\sigma_A}\right)\tilde{\gamma}_G. \tag{14}$$

With the aid of (3) and (5), we obtain for environmental quality ($E \equiv e(A) - aY$):

$$\tilde{E} = -(t_N/\alpha_E)(\tilde{a} - \epsilon_L \tilde{t}) + (\omega_A/\alpha_E)\tilde{A}, \tag{15}$$

where $\alpha_E \equiv (t_N/a)\,E/Y$. Environmental quality improves if public abatement rises or the emission–output ratio (a) falls. A higher tax rate improves (worsens) environmental quality if labour supply slopes upwards (backwards). Substituting (8) and (12) into (15), we obtain:

$$\alpha_E \tilde{E} = -t_N\left\{1 - \left[\frac{t_N V(\sigma_M - 1)^2}{\kappa\sigma_M}\right]\right\}\tilde{a} + \left\{\frac{\omega_A}{\sigma_A} + \left[\frac{t_N^2 V(\sigma_M - 1)^2}{\kappa\sigma_M}\right]\right\}\tilde{\gamma}_E$$
$$+ \left\{\frac{\omega_A}{\sigma_A} - \left[\frac{t_N \Delta(\sigma_M - 1)}{\kappa\sigma_M}\right]\right\}\tilde{\gamma}_G. \tag{16}$$

II.c. More concern about the environment

Greener preferences ($\tilde{\gamma}_E > 0$) raise both the non-distortionary tax rate and public abatement (see (8)). If labour supply slopes upwards ($\sigma_M > 1$), the larger non-distortionary level of the tax rate depresses the MCPF and makes public spending cheaper. The associated higher tax rate decreases private utility but increases overall public spending. If the elasticity of effectiveness of public abatement (σ_A) is small, public abatement rises substantially. Hence, despite the rise in the tax rate and overall public spending, public consumption (being residually determined) may fall. The higher tax burden changes the composition of private demand away from private consumption goods towards leisure ($\tilde{V} > \tilde{C}$). As $\sigma_M > 1$, this substitution effect outweighs the decline in demand for leisure on account of the negative income effect associated with the higher tax level. Hence, greener preferences reduce employment so that environmental quality is improved through a lower level of economic activity and emissions as well as through more public abatement (i.e. a cleaner composition of activity).

However, if labour supply bends backwards ($\sigma_M < 1$), more concern for the environment raises the MCPF. In this case, the higher non-distortionary level of the tax rate increases the MCPF (see (4)) and makes public spending more expensive. Hence, the tax rate and the level of public spending fall while private utility rises. The lower tax burden induces households to shift away from leisure towards consumption ($\tilde{C} > \tilde{V}$). In this case, the increase in leisure due to the positive income effect associated with a lower tax level offsets the substitution effect (as $\sigma_M < 1$). Employment, activity and emissions thus fall. The fall in overall public spending together with the rise in public abatement (see (8)) imply that public consumption must fall. Public consumption is thus

crowded out by both more abatement (i.e. cleaner composition of public spending) and by a lower tax rate yielding a lower level of overall public spending.

PROPOSITION 1. *Greener preferences reduce employment and emissions, unless labour supply is inelastic. Environmental quality improves also due to additional public abatement. If labour supply slopes upwards (downwards), the MCPF and the private component of utility fall (rise) while the tax rate rises (falls). Public consumption increases only if a large elasticity of the effectiveness of public abatement contains the rise in public abatement and at the same time an upward-sloping labour supply curve raises the overall level of public spending.*

Green and red preferences are thus incompatible, in the sense that environmental quality and public consumption do not move together, if there is a lot of scope for public abatement or if labour supply bends backwards. However, if the elasticity of the effectiveness of public abatement and the (uncompensated) labour supply elasticity are large and positive, public consumption increases so that green and red preferences are compatible. In that case, public abatement does not rise much while employment falls substantially. Hence, most of the improvement in environmental quality is achieved through a lower level rather than a cleaner composition of economic activity. A higher emission–output ratio (a) induces the same effects on the MCPF, the tax rate, private utility and employment as an increase in environmental concern (γ_E), but does not affect public abatement. If labour supply slopes upwards (downwards), the MCPF falls (rises) so public consumption rises (falls) while private utility decreases (increases). The deterioration of the environment induced by the higher emission–output ratio is reduced by the fall in output. In fact, a rise in the emission–output ratio may improve environmental quality if σ_M is very small (see (16)).

II.d. More priority for public consumption

More desire for public consumption ($\tilde{\gamma}_G > 0$) lowers both the non-distortionary tax rate and public abatement (see (8)). The tax rate rises and private utility falls in order to make room for public consumption. If labour supply slopes upwards (bends backwards), the MCPF rises (falls) and employment falls (rises). Overall public spending expands while its composition changes away from abatement towards public consumption. Environment quality worsens due to the fall in public abatement and, if labour supply bends backwards, the increase in output and thus emissions. However, if the elasticity of labour supply is large and positive and the elasticity of the effectiveness of public abatement (σ_A) is large, the environment improves because the beneficial effect of the fall in output and emissions outweighs the adverse effect of less abatement. While economic activity declines substantially due to the disincentive effects of a higher tax burden (as σ_M is large), the composition of activity does not become much dirtier (as σ_A is large). Green and red preferences are thus compatible if the level of activity falls while the composition of activity is not affected much.

PROPOSITION 2. *More concern about public consumption increases the tax rate and decreases private utility and public abatement. If the labour supply curve slopes upwards (downwards), employment and emissions fall (rise). Unless substitution effects in labour supply are strong and the elasticity of the effectiveness of public abatement is large (i.e. both* σ_M *and* σ_A *are large), environmental damages increase so that red and green preferences are incompatible.*

III. IMPERFECT SUBSTITUTION BETWEEN PRIVATE UTILITY AND PUBLIC GOODS

To allow for imperfect substitution between the private component of utility and public consumption, consider the following social welfare function:

$$W \equiv NQ[M(C, V), G] + N\gamma_E[e(A) - aY] \tag{17}$$

where $Q(M, G) = (M^\zeta + \gamma_G G^\zeta)^{1/\zeta}$ with $\zeta < 1$ and $\sigma_Q \equiv (1-\zeta)^{-1} > 0$ is the elasticity of substitution between M and G. This CES-specification reduces to (2) if σ_Q tends to infinity. Private behaviour (5) is unaffected. Public consumption follows from the modified Samuelson rule:

$$NQ_G/Q_M M_C = \eta \equiv \mu/\lambda. \tag{18}$$

For public abatement and the non-distortionary level of the tax rate, we obtain:

$$e'(A) = a/t_N, \quad t_N \equiv (Na\gamma_E/Q_M M_C)/\eta = a\gamma_E/Q_G. \tag{19}$$

Expression (4) for the MCPF is unaffected.

Loglinearising the modified Samuelson rule (18), we obtain:

$$\tilde{G} - \tilde{M} = \sigma_Q[\tilde{\gamma}_G + (V/L)\,\tilde{M} - \tilde{\eta}]. \tag{20}$$

A higher priority for public consumption (γ_G), a higher consumption wage (or higher M), and a lower MCPF induce a shift away from the private component of utility to public consumption, particularly if public consumption and private utility are good substitutes.

Loglinearising (19), we obtain:

$$\tilde{A} = (\tilde{t}_N - \tilde{a})/\sigma_A, \quad \tilde{t}_N = \tilde{a} + \tilde{\gamma}_E - [1 + \alpha_G(\sigma_Q - 1)^{-1}]\,\tilde{\gamma}_G - (1-\alpha_G)\,\sigma_Q^{-1}(\tilde{M} - \tilde{G}) \tag{21}$$

where $\alpha_G \equiv GQ_G/Q = \gamma_G[\gamma_G + (M/Q)^\zeta]^{-1}$. Substitution from public consumption towards private utility (i.e., $\tilde{M} > \tilde{G}$) raises the marginal utility of public consumption. This reduces the non-distortionary level of the tax rate as this part of the tax is defined in terms of public revenue. Public abatement falls in response to the lower non-distortionary level of the tax rate.

Substituting (21) into (10) and then into (20), we obtain:

$$\tilde{G} = \tilde{M} + \sigma_Q \left\{ \frac{\left[1 - t - \epsilon_L\left(t + \dfrac{t_N \alpha_G}{\sigma_Q - 1}\right)\right]\tilde{\gamma}_G + t_N \epsilon_L(\tilde{a} + \tilde{\gamma}_E) + \dfrac{V}{L}\kappa\sigma_M \tilde{M}}{1 - t - \epsilon_L(t - t_N \alpha_G)} \right\}. \tag{22}$$

A higher level of private utility (M) raises public consumption through two

channels. The first channel, represented by the second term at the right-hand side of (22), is a reduction in the MCPF. This is due to the substitution away from leisure as a result of higher private utility (i.e. $\tilde{V} < \tilde{C}$ if $\tilde{M} > 0$), see (5)). The second channel involves imperfect substitution between private utility and public consumption. If private utility and public consumption are poor substitutes, the two components of social utility move together.

The MCPF-schedule (22) shifts upwards when the weight given to public consumption (γ_G) increases (see Fig. 1). If labour supply slopes upwards

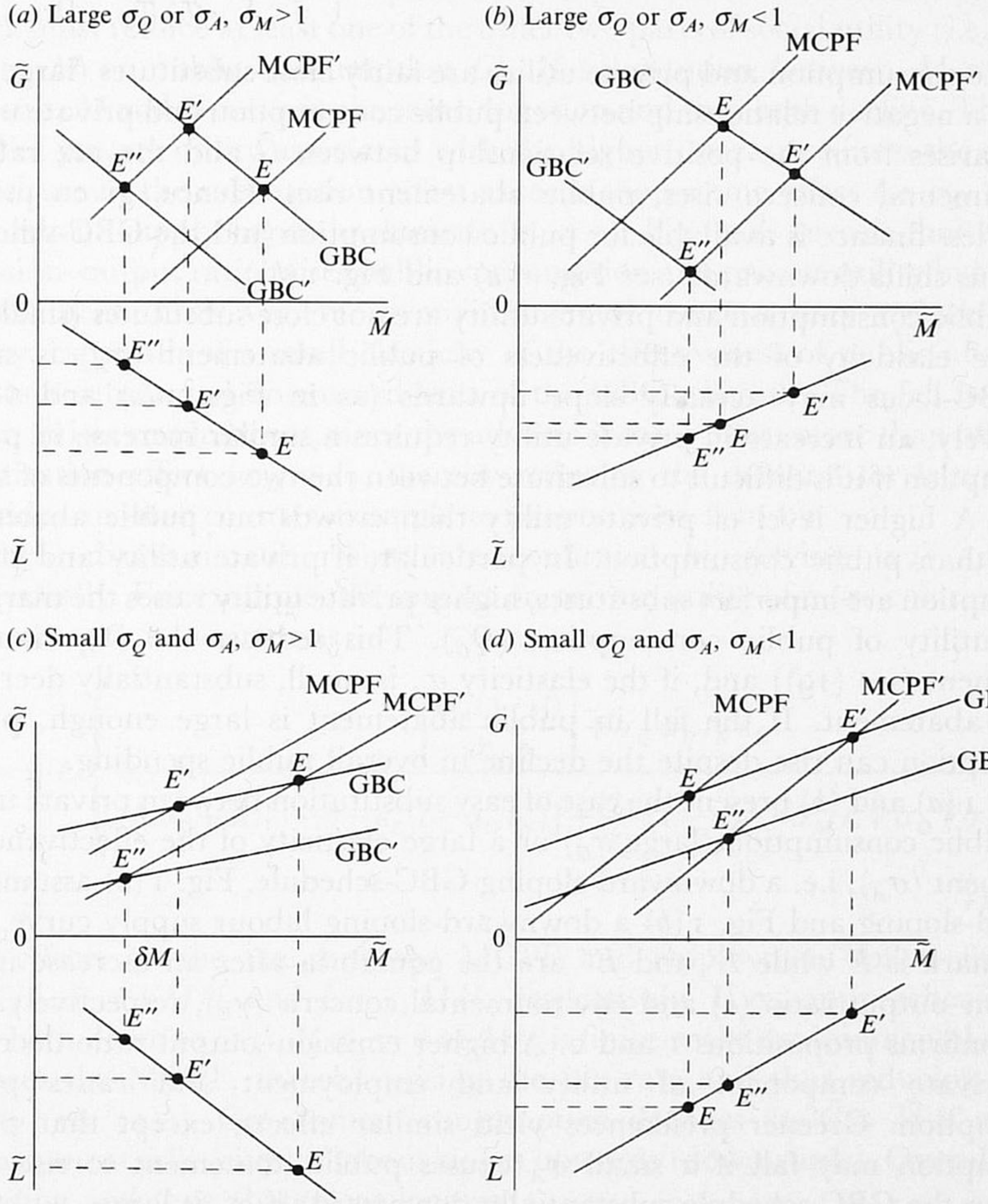

Fig. 1. Effects of an increase in environmental concern on public consumption and private utility.

(downwards), the MCPF-schedule shifts upwards (downwards) in response to an increase in environmental concern (γ_E) or an increase in the emission–output ratio (a). If private utility and public consumption are perfect substitutes, the MCPF-locus is vertical (cf. (13)). If private utility and public

consumption are perfect complements ($\sigma_Q = 0$), the MCPF-schedule corresponds to the 45°-line and is unaffected by changes in environmental concern or the emission–output ratio.

The government budget constraint may with the aid of (7) and (21) be loglinearised as:

$$\tilde{G} = -\left(\frac{\omega_A}{\sigma_A}\{\tilde{\gamma}_E - [1 + \alpha_G(\sigma_Q - 1)^{-1}]\,\tilde{\gamma}_G\} + \left\{\frac{\Delta}{L} - \left[\frac{\omega_A(1-\alpha_G)}{\sigma_A\sigma_Q}\right]\right\}\tilde{M}\right)$$
$$\times\left\{\omega_G + \left[\frac{\omega_A(1-\alpha_G)}{\sigma_A\sigma_Q}\right]\right\}^{1}. \quad (23)$$

If public consumption and private utility are fairly close substitutes (large σ_Q), there is a negative relationship between public consumption and private utility which arises from the positive relationship between $\tilde{G}$ and the tax rate. If environmental concern rises, public abatement rises. Hence, given private utility, less finance is available for public consumption and the GBC-schedule (23) thus shifts downwards (see Fig. 1 (*a*) and Fig. 1 (*b*)).

If public consumption and private utility are not close substitutes (small σ_Q) and the elasticity of the effectiveness of public abatement (σ_A) is small, the GBC-locus may actually slope upwards (as in Figs. 1 (*c*) and 1 (*d*)). Intuitively, an increase in private utility requires a similar increase in public consumption if it is difficult to substitute between the two components of social utility. A higher level of private utility then crowds out public abatement rather than public consumption. In particular, if private utility and public consumption are imperfect substitutes, higher private utility raises the marginal social utility of public consumption (Q_G). This reduces the Pigovian tax component (see (19)) and, if the elasticity σ_A is small, substantially decreases public abatement. If the fall in public abatement is large enough, public consumption can rise despite the decline in overall public spending.

Figs. 1 (*a*) and (*b*) present the case of easy substitution between private utility and public consumption (large σ_Q) or a large elasticity of the effectiveness of abatement (σ_A), i.e. a downward-sloping GBC-schedule. Fig. 1 (*a*) assumes an upward-sloping and Fig. 1 (*b*) a downward-sloping labour supply curve. The benchmark is E while E' and E'' are the equilibria after an increase in the emission–output ratio (a) and environmental concern (γ_E), respectively. Fig. 1 (*a*) confirms propositions 1 and 2. A higher emission–output ratio decreases the private component of utility and employment and raises public consumption. Greener preferences yield similar effects, except that public consumption may fall if a small σ_A causes public abatement to rise a lot (shifting the GBC-schedule substantially downward) if σ_Q is large.

Fig. 1 (*b*) (with large σ_Q and σ_A but with $\sigma_M < 1$) reveals that a higher emission–output ratio raises private utility but reduces public consumption and employment, thus confirming propositions 1 and 2. However, Fig. 1 (*b*) also illustrates the possibility of a counter-example to propositions 1 and 2 in the case of a green shock. If labour supply bends backwards ($\sigma_M < 1$) and the elasticity of the effectiveness of public abatement (σ_A) is small, the GBC-schedule shifts

downward a lot. More environmental concern may then reduce private utility (as well as public consumption) if σ_Q is finite. The associated adverse income effect reduces the demand for leisure, thereby raising employment. Accordingly, for this case we confirm the 'double dividend' hypothesis, i.e. greener preferences boost environmental quality and employment.

Figs 1 (c) and 1 (d) present the case where substitution between public consumption and private utility is difficult (low σ_Q) and the elasticity of the effectiveness of public abatement (σ_A) is small so the GBC-schedule slopes upwards. If also labour supply slopes upwards, then Fig. 1 (c) reveals that private utility, public consumption and employment fall. Intuitively, a green shock must reduce at least one of the other two parts of social utility (i.e. private utility M or public consumption G). If substitution between M and G is difficult, M and G move in the same direction and thus both decline. The lower level of private utility associated with the higher tax rate reduces the demand for leisure as the substitution effect exceeds the income effect (as $\sigma_M > 1$).

If labour supply bends backwards ($\epsilon_L < 0$), Fig. 1 (d) reveals that a higher emission–output ratio raises public consumption and private utility but reduces employment. However, more environmental concern may reduce private utility, especially if a small elasticity of the effectiveness of public abatement causes a substantial downward shift of the GBC-schedule. The fall in private utility raises employment, since the adverse income effect more than offsets the substitution effect ($\sigma_M < 1$), thereby reducing the demand for leisure. This provides another counter-example to propositions 1 and 2.

These diagrammatic results are confirmed by solving (22) and (23) analytically. For example, the impact on private utility of more environmental concern may be written as:

$$\tilde{M} = -L \left\{ \frac{\left[\frac{\omega_A(1-t)}{\sigma_A \eta}\right] + \sigma_Q \omega_G t_N \epsilon_L}{(L\omega_G + \Delta)[1 - t - \epsilon_L(t - \alpha_G t_N)] + \frac{\omega_A}{\sigma_A}(1-\alpha_G) V\sigma_M \kappa + \sigma_Q V\sigma_M \kappa \omega_G} \right\} \tilde{\gamma}_E. \quad (24)$$

The effects on the tax rate, the MCPF and employment follow from $\tilde{t} = -\tilde{M}/L$, $\tilde{\eta} = V\tilde{M}/L$ and $\tilde{L} = \epsilon_L \tilde{M}/L$, respectively. If σ_Q approaches infinity, (24) boils down to (13). If $\sigma_Q = 0$ and σ_A is finite, more environmental concern reduces the MCPF, thereby raising the tax rate and thus reducing private utility (see (24)). Government consumption declines (as $G = \tilde{M}$ if $\sigma_Q = 0$). Employment falls (rises) if labour slopes upwards (downwards). Overall public spending and thus abatement increase.

IV. CONCLUDING REMARKS

A more ambitious environmental policy raises the non-distortionary tax rate and boosts public abatement. In general, this lowers labour supply and economic activity. If substitution effects dominate income effects in labour

supply, a greener policy raises the tax rate and public spending. In this case, public consumption rises if most of the improvement in environmental quality is achieved through lower production rather than more abatement. However, if the environment improves mainly due to public abatement and employment does not fall too much, public consumption falls. In general, more environmental concern reduces employment as consumption of leisure is clean while production pollutes the environment. However, if private utility and public consumption are poor substitutes, the elasticity of the effectiveness of public abatement is small and labour supply bends backwards, more environmental concern may raise employment. The environment is then improved through an expansion of public abatement rather than through an increase in leisure and a drop in emissions. The rise in public abatement is financed by a higher tax rate, a broadening of the tax base, and a cut in the level of public consumption. While the *level* of economic activity increases, the *composition* of that activity becomes more friendly to the environment. This is a channel through which the 'double dividend' hypothesis can be given some support within a framework of optimal taxation.

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